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Finite Element Analysis of F1 Halo Safety Structure

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Abstract: The Federation Internationale de L'Autobile (FIA) has been working on improving safety of drivers in open wheel racing series. Numerous incidents caused serious impacts on drivers' lives. The car-to-car collision, car to environment collision and injuries due to flying debris are common threats to these drivers. In 2016 the introduction of Halo surrounding the cockpit was appreciated by the FIA. The following study includes the analysis of this Halo system using Finite Element Analysis (FEA). The dynamic, static and modal analysis is carried out with the help of Simscale software and the results obtained showed the values under permissible levels.
Keywords: Finite Element Analysis, Static Analysis, Modal Analysis, Dynamic Analysis, F1 Halo, FIA.

I. INTRODUCTION

Safety is a paramount in motorsports. For years motor sport has had serious incidents affecting the drivers. The FIA had no choice but to strive to minimize the risk of drivers' lives. The engineers came up with a solution with the Halo concept. It got its name from its resemblance of angel's Halo. Halo safety system protects the driver's head from external injuries. Without halo the driver's head is exposed to the external flying debris which could be fatal in some incidents. Halo is designed for open-wheel racing series vehicles. It is a curved bar placed around the driver's cockpit. It is connected to the vehicle frame via three points.

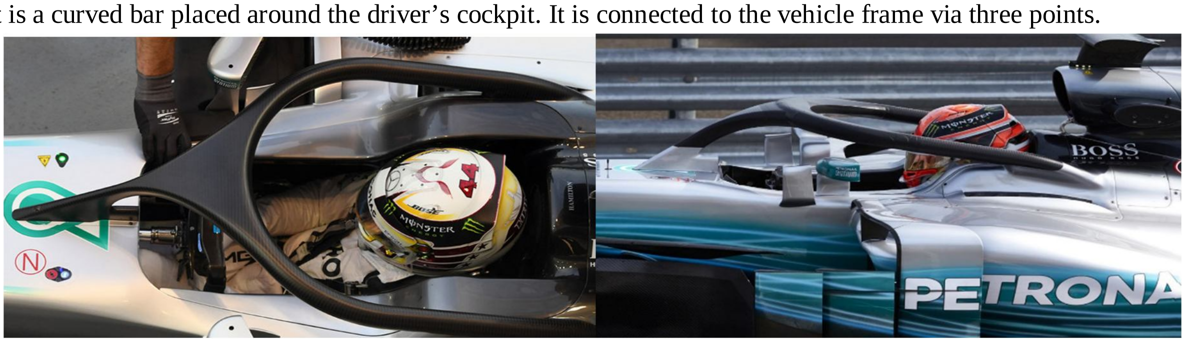

Figure 1: F1 Halo

There are three parts of Halo, a) the front middle section called as 'V transition', b) the tube around the cockpit and 3) rear mounts. The design provides the teams 20 mm area of freedom for other modification. The tests of the halo design were carried out in 2016 and 2017 and the FIA made it mandatory on every vehicle from open-wheel racing series in 2018. The tests of FIA for Halo consists of three types – 1) collision between two vehicles, 2) contact between a vehicle and the surrounding environment and 3) collisions with vehicles and debris. A test_known as chassis homologation test is carried out by applying loads from different positions on Halo. In the test a 116kN of force is applied on top of the Halo and expected it to withstand the force for at least 5 seconds. It must withstand longitudinal forces of 46kN and 83kN on the front. Also, side lateral force of 93kN is applied. The Halo has to withstand 125kN of force from above for 5 seconds without failure of any components and also from the side it should withstand with the same. The Halo is made from the Titanium and weighs around 7 kg. Unlike manufacturing the vehicle parts and other components by the teams, Halo is chosen by the FIA to be manufactured by three external manufacturers, these are CC Autosport, SS Tube Technology and V system. Adding Halo adds different challenges for teams such as weight challenge, aerodynamic challenge, structural challenge etc. In the studies of FIA, it was found that the addition of halo would protect the driver 17% of the time than 0% without halo.[1]–[3]
The material used for manufacturing of Halo under the regulations of FIA is Ti6Al4V Grade 5, a Titanium alloy. This material is used in aerospace engineering due to its high strength and stiffness yet low density characteristics. The material has excellent corrosion resistance and is heat treatable in sections up to 25mm. The mechanical properties of this material are given below in tabular form. [4]–[6]

Property	Value	Unit
Density	4.512	Mg/m^3
Poisson's Ratio	0.31-0.37	
Tensile Strength	862-1200	MPa
Young's Modulus	110-119	Gpa
Bulk Modulus	96.8-153	Gpa
Shear Modulus	40-45	Gpa
Elastic Limit	786-910	Mpa

Table 1: Ti6Al4V Grade 5 Mechanical Properties

II. METHODOLOGY

The 3D model of F1 Halo was subjected to FEA which includes static, dynamic and modal analysis as mentioned. Foe this the diagram below (figure 2) shows the subjected structure.

Figure 2: 3D model of proposed Halo design

The input values needed for FEA are calculated and noted. The model is then imported in Simscale software. Mesh is generated by putting the finest value.

Figure 3: Meshed model

Thereafter, the halo was put for static analysis at first. A static analysis is conducted to study the load bearing capacity of a structure. While performing a static structural analysis steady loading and response conditions have to be assumed. The Halo is provided with Titanium material and physical properties are provided with the help of above table. A load of 128kN is applied on the front and side (different simulations are carried out) of the Halo. The total displacement variation results and the results of Von Mises Stress obtained from the static analysis after applying both the forces.

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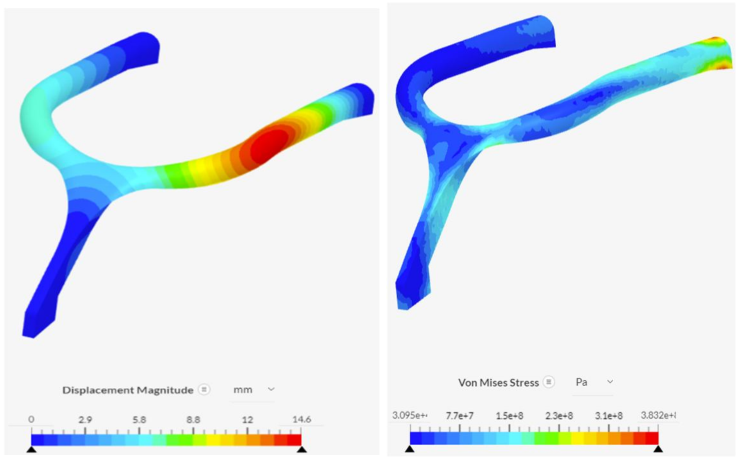

Figure 4: When load is applied on the side

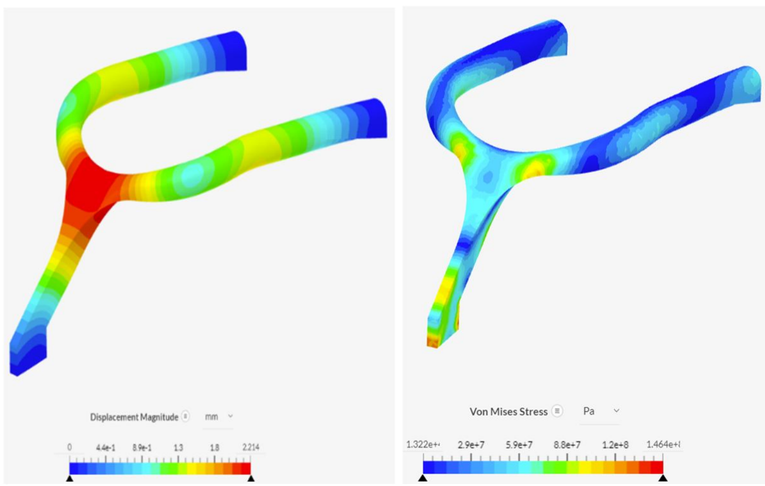

Figure 5: When load is applied on the front

Next, dynamic analysis is done. The dynamic analysis comes into picture when a body is subjected to particular acceleration or deceleration where load changes rapidly. Here, inertial forces will be present and to capture their effects dynamic analysis is needed. For this analysis, a wall is placed at a distance of 1m from the Halo. The material chosen for the wall was concrete and Halo the same. The halo is then provided the velocity of 60m/s against the wall. The results are shown below.

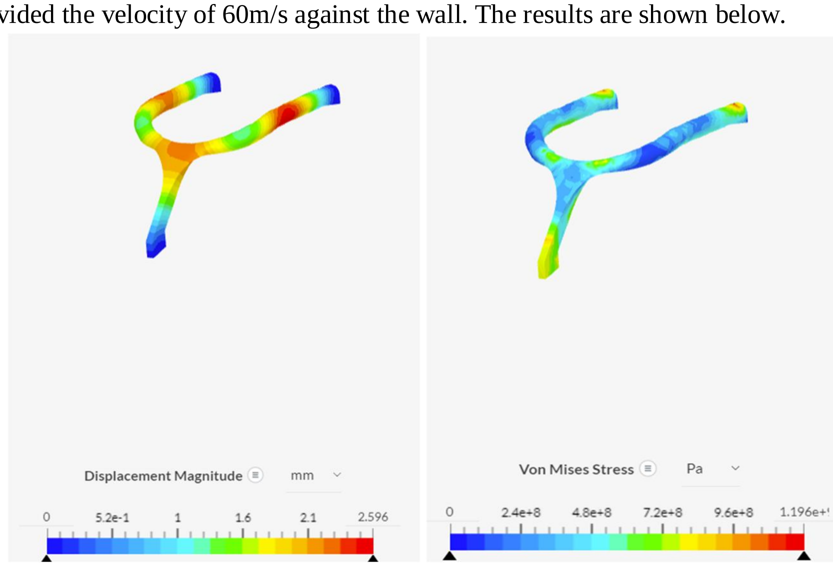

Figure 6: Results of dynamic analysis

Further, a modal analysis is carried out. Modal analysis helps identify natural frequencies and modal shape of the system. It also helps in predicting dynamic behaviours of a system. The Halo set for modal analysis provided the maximum displacement magnitude.

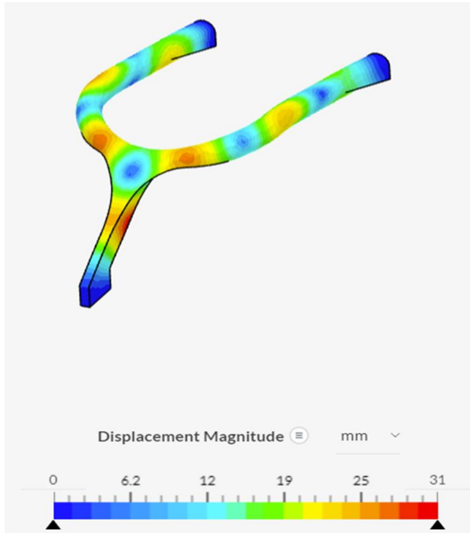

Figure 7: Result obtained from modal analysis

III. RESULTS & CONCLUSION

The 3-D model of halo is subjected to static structural, dynamic and modal analysis. The results of each analysis are as follows,

A. The Results of Static Structural Analysis

1) The result from the side impact force shows a maximum of 14.6 mm displacement value.
2) The result from the front impact force shows a maximum of 2.2 mm displacement value.
3) The Von Mises Stress for front impact force ranges from 1.322e+4 to 1.464e+8.
4) The Von Mises Stress for side impact force ranges from 3.095e+4 to 3.832e+8

B. The Results of Dynamic Analysis

The maximum von mises stress induced is 1.196e+9 Pa and maximum displacement magnitude is 2.596mm.

C. The Results of Modal Analysis

The maximum displacement value obtained is 31mm.

As the values of these analysis are under the permissible safety limits, it can be concluded that these analysis' data provides the safety data needed for a halo to get the safety rating.

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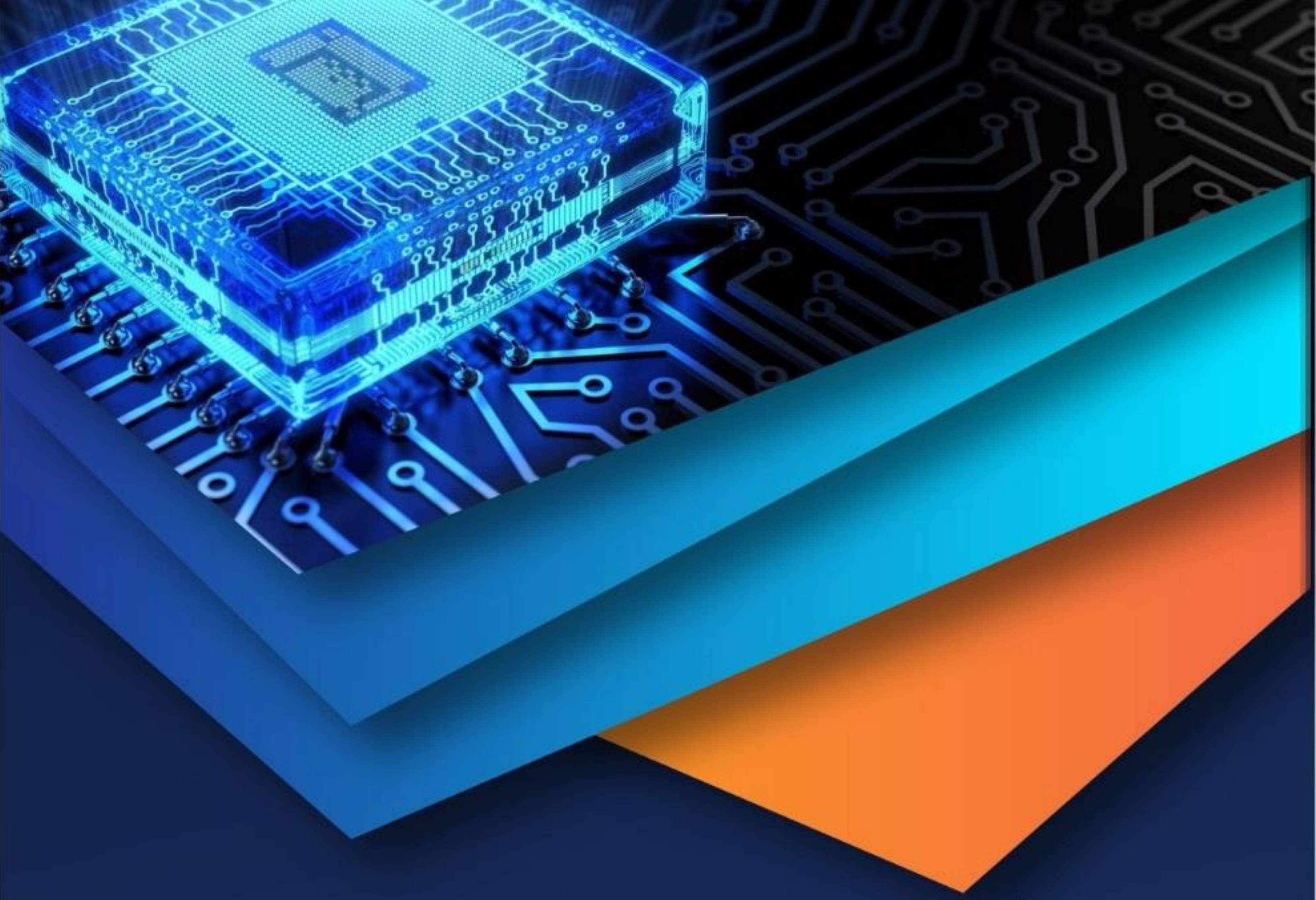

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